



Information Summaries

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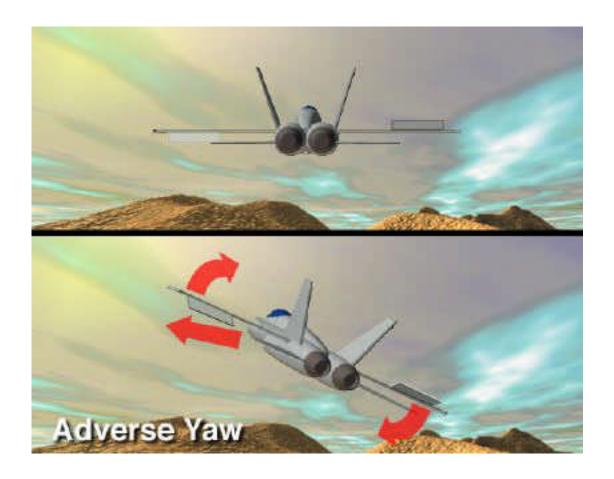
Aileron Roll

Background

All airplanes turn by tilting the lift vector (banking), then increasing the lift to cause a change in the direction of flight. Highly maneuverable fighter airplanes must have an ability to generate a small turn radius, but must also have an ability to quickly change the direction of the turn. This means that the pilot must be able to change bank angle (roll) very quickly to re-orient the lift to the direction of the desired turn.



For less agile, cargo-type airplanes the rapid roll capability is not as important, but the rolling characteristics must still be identified in order to assess the pilot's capability to respond to turbulence, fuel or thrust asymmetries, or other roll-producing disturbances. The roll requirements are expressed in terms of a maximum roll rate for full aileron, and a roll acceleration requirement expressed as "time to roll through 90 degrees of bank angle". Aileron roll tests are used to identify other rolling characteristics besides the maximum roll rate capability. Due to the aerodynamic coupling that links the roll and yaw axes of an airplane through sideslip, pure roll control inputs often produce unwanted sideslip excursions. Usually the coupling is in the form of "adverse yaw". The aileron controls that are used to start a roll will cause the nose to swing (yaw) in the opposite direction. That is, aileron control to start a right roll will cause the nose to swing to the left.



Identifying the magnitude of these excursions, and assessing the pilot's ability to compensate by use of the rudder, are also objectives of aileron roll tests.

Fighter aircraft with high roll rate capability often experience another coupling phenomenon known as "inertial coupling". Inertial coupling may occur if there is a large difference between the roll moment of inertia and the yaw or pitch moments of inertia for the airplane. This is often the case for fighters which have short stubby wings (low roll inertia) and long fuselages with heavy engines, electronics, fuel, etc. (high pitch and yaw inertia). When such an airplane is exposed to high roll rates along the fuselage axis, the high mass concentration along the fuselage may cause it to behave like a "dumbbell". The centrifugal force due to the roll will cause the nose and tail to try to swing out perpendicular to the rotation axis.



1. Specific Objective of the Test

There are four equally important objectives to the aileron roll test for a particular flight condition:

- ■Determine the maximum roll rate capability
- ■Determine the time to bank through 90 degrees
- ■Determine the relationship between the commanded aileron and the actual roll rate achieved. (ideally, a linear relationship)
- ■Determine the aerodynamic and/or inertial coupling characteristics of the airplane while rolling.

2. Critical Flight Conditions

There are several conditions that will influence the rolling characteristics of an airplane. The important ones are:

- Airspeed
- ■Mach number
- ■Angle of Attack
- ■Configuration (flaps and landing gear position, external stores)

Both the aerodynamic coupling (adverse yaw), and the inertial coupling characteristics are difficult to predict accurately for a new airplane. The consequences of loss of control during a roll due to coupling are often abrupt and disastrous. Aileron roll tests are therefore done quite cautiously starting with small aileron deflections and small bank angle excursions. Eventually tests will be expanded to include maximum aileron deflections and, for fighters, 360 degrees, or even 720 degrees, of bank (one or two complete rolls).

Both aerodynamic and inertial coupling characteristics are strongly influenced by low directional or longitudinal stability. Regions of low stability (such as transonic conditions) will be approached very cautiously using small increments in Mach number as well as a buildup in aileron deflections.

3. Required Instrumentation

The parameters usually measured and recorded during an aileron roll are shown in Table (1-1). Notice that this is a large list of measurements, including nearly all of the dynamic instrumentation on the airplane. Each measurement contributes to the understanding of the maneuver dynamics, and some of the subtle interactions that are often caused by aerodynamic or inertial coupling.

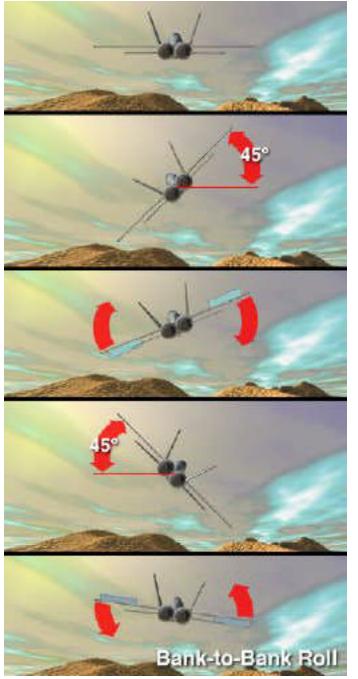
A continuous time history of these parameters is needed for the trim point, and throughout the actual roll maneuver. A sampling rate of at least 10 data samples every second is necessary to accurately record the maneuver, and each data sample must be accurately time correlated with the data samples of the other parameters. That is, we must be able to relate a particular measurement of aileron deflection with a measurement of roll rate and bank angle at the same instant in time.

4. Starting Trim Point

The flight test engineer will establish a table of flight conditions where aileron rolls are desired. This table usually calls for particular speeds, altitudes and aircraft configurations covering the entire flight envelope of the airplane. Each maneuver is usually repeated at the same flight condition, but for different values of commanded aileron deflection. A typical sample table of flight conditions for aileron rolls is shown in Table (1-2).

A test begins with the initial trim point. The pilot establishes the airplane in level flight at one of the desired flight conditions of speed, altitude and power setting. The pilot then uses the trim devices in the airplane's

control system to allow the airplane to continue in stable, level flight, but with the pilot's hands and feet off of the controls. A short data recording is taken of this condition, usually referred to as a "trim shot".



5. Description of an aileron roll

There are two methods for accomplishing the aileron roll test, depending on the type of airplane and the expected roll rate. For large airplanes or for small aileron deflections the maneuver will be initiated from a starting left bank angle of 45 degrees. A "chain stop", or some other temporary stick or wheel restraint, is often used to provide a firm and repeatable aileron deflection for each maneuver. Once the airplane is stabilized in a 45 degree left bank with zero roll rate, the pilot will abruptly move the stick right to the stick stop, and hold it there until the airplane has rolled to the right through at least 90 degrees of bank (past 45 degrees of right bank). The pilot will then disengage the stick stop and restabilize the airplane at 45 degrees of right bank angle. When stable, the pilot will abruptly move the stick left to the stick stop and hold it there until the airplane has rolled left through at least 90 degrees of bank. This maneuver sequence is usually referred to as "bank to bank rolls".

For fighters or conditions where high roll rates are expected, the roll test begins in wings-level flight. The pilot will move the stick abruptly to the stick stop in one direction, and will allow the airplane to roll completely around, recovering back to wings-level flight. This maneuver is referred to as a "360 degree roll".

The pilot will attempt to move the stick or wheel only laterally so that there are no unwanted pitch commands during the roll.

After each roll the pilot will qualitatively assess the coupling characteristics that were observed. If telemetry is being used, a flight test engineer may perform a brief quantitative assessment to measure the maximum normal and lateral accelerations that were experienced. If the observed values are well within the airplane

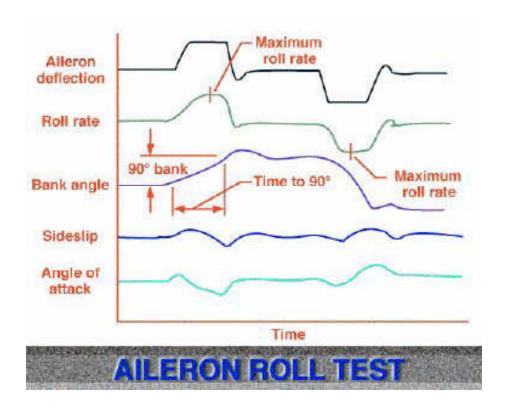
limits, a higher aileron deflection, or higher speed, will be used for the next test series, otherwise the test will be terminated.

6. Measures of Success

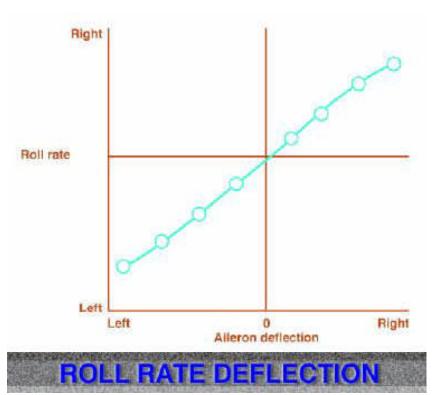
- A successful aileron roll will meet the following test criteria:
- ■All instrumented parameters recorded properly.
- ■The desired aileron deflection was maintained through at least 90 degrees of bank angle change.
- ■A maximum steady state roll rate was achieved before the recovery was initiated.
- ■There were no significant elevator commands resulting from the pilot's aileron input.

■Coupling characteristics showed consistent trends with other aileron roll tests.

A sample bank-to-bank aileron roll test is shown.



The maximum roll rate associated with the commanded aileron deflection can be read directly from the time



history. After a complete aileron roll test sequence has been completed at one flight condition, the resulting maximum roll rates can be plotted as shown.

If the points do not lie essentially in a straight line, the roll characteristics of the airplane will appear to the pilot to be unpredictable. Non-linearities can be caused by adverse yaw coupling, structural bending or blowback of the aileron actuators.

Time-to-bank measurements can be taken by measuring the elapsed time from the first initiation of pilot action (aileron force greater than zero), to the time when the airplane passed through 90 degrees of bank angle change from the initial value. The time-to-bank numbers thus derived must be less than those specified in the aircraft handling qualities specification.

Aerodynamic and inertial coupling characteristics are more difficult to analyze and often require a simulation or other math-

modelling process to fully understand the complex interactions which are usually observed.

Table 1-1
Listing of Instrumentation Parameters

Parameter	Used for		
Airspeed			
Pressure Altitude	Compute mach and dyn. pres.		
Outside Air Temperature	r		
Normal acceleration	Assess coupling		
Elevator Position	Inadvertent pilot inputs		
Angle of Attack	Assess coupling		
Pitch Rate	Assess coupling		
Angle of Sideslip	Assess coupling		
Lateral acceleration	Assess coupling		
Yaw rate	Assess coupling		
Roll rate	Measure achieved roll rate		
Aileron Position	Measure commanded aileron		
Rudder Position	Measure commanded rudder		
Bank angle	Measure time to reach 90 degree		

Table 1-2
Aileron Roll Flight Test Conditions

Config.	Alt.	Airspeed	(Mach)	Aileron Deflection.
		140	.26	1/4, 1/2, 3/4, Full
	10000	200	.36	1/4, 1/2, 3/4, Full
		250	.45	1/4, 1/2, 3/4, Full
		300	.54	1/4, 1/2, 3/4, Full
Clean		200	.44	1/4, 1/2, 3/4, Full
	20000	250	.55	1/4, 1/2, 3/4, Full
		300	.65	1/4, 1/2, 3/4, Full
		350	.75	1/4, 1/2, 3/4, Full
		200	.54	1/4, 1/2, 3/4, Full
	30000	250	.67	1/4, 1/2, 3/4, Full
		300	.79	1/4, 1/2, 3/4, Full
		350	.90	1/4, 1/2, 3/4, Full
Gear, Flaps	5000	120	.20	1/4, 1/2, 3/4, Full
		140	.23	1/4, 1/2, 3/4, Full
		180	.30	1/4, 1/2, 3/4, Full